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MULTI-FIBER COMPOSITES

First Quarterly Report on

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I. INTRODUCTION

The objective of this program is to develop resin matrix composites having improved resistance to foreign object damage (FOD). Approaches to be investigated include hybridization of the reinforcement to incorporate both high modulus and high strain energy in the composite, study of the effects of ply configuration on the response of specimens to impact loading, and leading edge protection schemes.

The program is divided into three technical tasks which follow the approaches outlined above. During Task I hybrid combinations of carbon/glass, boron/glass, and carbon/boron/glass will be investigated having both epoxy and thermoplastic matrices. In addition, superhybrid materials involving combinations of isotropic metals, metal matrix composites, and carbon/resin will be studied. Static properties will be measured on all materials, and ballistic testing will be conducted on blade-like specimens with gelatin projectiles.

The effects of ply configuration on impact resistance will be studied in Task II. Three materials will be selected from Task I results and each will be fabricated into blade-like ballistic specimens having four different ply configurations. These specimens will be ballistically tested at two angles of incidence.

In Task III leading edge protection schemes will be evaluated on ballistic specimens made from the most impact resistant material/ply configuration found in Task II.

II. TECHNICAL PROGRESS SUMMARY

This report summarizes work during the first quarter of the program. All materials were ordered and received and effort was concentrated on specimen fabrication. This work is described below in further detail.

2.1 Specimen Fabrication

The materials to be studied under the program are listed in Table I. Under Task I each material is to be evaluated in a series of static tests including tension, compression, shear, flexure, and torsion, and impact tests including pendulum impact and ballistic impact. The ballistic impact tests will be conducted on blade-like test specimens having the geometry described by Friedrich (Ref. 1). The impacting projectile will be 2.54 cm (1 in.) gelatin and the angle of incidence to the specimen leading edge will be 30°. Two specimens of varying leading edge thickness will be tested for each material. Results of the ballistic tests will be qualitatively assessed by visual examination and quantitatively assessed by torsional stiffness retention measurements.

During the first quarter all blade-like ballistic specimen fabrication was completed. The basic ply configuration for the conventional and advanced hybrids was ±45°, 0° interspersed. The specific layup varied somewhat from one material to another due to differences in ply thickness. The general layups for the super-hybrids are given in Tables II, III, and IV. All plies are at 0° since the torsional stiffness requirements are met by the titanium and/or boron/aluminum layers. The Ti-6-4 was etched prior to lamination, while the B/Al was grit blasted and solvent rinsed. The graphite/epoxy used in all superhybrids was AS/PR-288.

Pretest torsional stiffness measurements are currently in progress on the ballistic specimens. Upon completion of those tests, the specimens will be delivered to Pratt & Whitney Aircraft for ballistic impact testing.

2.2 Static Testing

Static testing of the materials is underway. First priority in fabrication was given to the ballistic specimens in order to facilitate scheduling of the test rig. Approximately half of the static specimens have been fabricated and submitted for test. The results available to date are given in Table V.

The flexural strengths of the boron/glass/epoxy composites are given as minimum values because the specimens bottomed out on the test fixture before ultimate failure. In each of the three tests there was evidence of some failure at a lower stress than reported in Table V. These were 156 ksi, 167 ksi, and 167 ksi for specimens 1, 2, and 3, respectively.

The instrumented pendulum impact tests were conducted on specimens having a nominal thickness of .254 cm (.1 in.) because it was found in Ref. 2 that the thin specimen produced better correlation with ballistic test data than did the standard specimen thickness of 1 cm (.394 in.). Both the load carrying capacity and the total energy are felt to be important parameters because they relate to damage threshold and resistance to catastrophic fracture, respectively.

III. PROBLEMS

There are no current problems.

IV. FUTURE WORK

Ballistic testing of blade-like specimens will be initiated. Fabrication and testing of static specimens will be continued.

REFERENCES

1. Friedrich, L. A.: Impact Resistance of Hybrid Composite Fan Blade Materials, NASACR-134712, May 1974.

2. Pike, R. A. & R. C. Novak: Design, Fabrication and Test of Multi-Fiber Laminants, NASA CR-134763, January 1975.

TABLE I

TASK I - MATERIALS

Conventional Hybrids

1. T-300/S-glass/epoxy (commercial)
2. T-300/S-glass/epoxy (contractor)
3. AS/S-glass/epoxy
4. AS/S-glass/boron/epoxy

Advanced Hybrids

1. Boron/S-glass/epoxy
2. Boron/S-glass/polysulfone
3. Boron/S-glass/polysulfone/AS/S-glass/epoxy

Superhybrids

1. $[\text{Ti-6-4/B-Al/AS/epoxy/Ti-6-4}]_S$
2. $[\text{Ti-6-4/AS/epoxy/Ti-6-4}]_S$
3. $[\text{Ti-6-4/B-Al/AS/epoxy}]_S$

TABLE II

SUPERHYBRID LAMINATE COMPOSITION

LAMINATE NO. 1

Ti-6-4, 3 mil
FM 1000 adhesive
Titanium, 3 mil
FM 1000
B/Al, 5.6 mil/6061
FM 1000
B/Al, 5.6 mil/6061
FM 1000
G/E
G/E
G/E
G/E
G/E
G/E
FM 1000
Titanium, 3 mil
FM 1000
G/E
G/E
G/E
G/E
G/E
G/E
FM 1000
B/Al
FM 1000
B/Al
FM 1000
Titanium, 3 mil
FM 1000
Titanium, 3 mil

TABLE III

SUPERHYBRID LAMINATE COMPOSITION

LAMINATE NO. 2

Ti-6-4, 3 mil
FM 1000
Titanium, 3 mil
FM 1000
G/E
G/E
G/E
G/E
G/E
G/E
G/E
G/E
G/E
G/E
FM 1000
Titanium, 3 mil
FM 1000
G/E
G/E
G/E
G/E
G/E
G/E
G/E
G/E
G/E
G/E
FM 1000
Titanium, 3 mil
FM 1000
Titanium, 3 mil

TABLE IV

SUPERHYBRID LAMINATE COMPOSITION

LAMINATE NO. 3

Ti-6-4, 3 mil
FM 1000
Titanium, 3 mil
FM 1000
B/Al, 5.6 mil/6061
FM 1000
B/Al, 5.6 mil/6061
FM 1000
G/E
G/E
G/E
G/E
G/E
G/E
G/E
G/E
G/E
G/E
G/E
G/E
G/E
G/E
FM 1000
B/Al
FM 1000
B/Al
FM 1000
Titanium, 3 mil
FM 1000
Titanium, 3 mil

TABLE V

HYBRID COMPOSITE MECHANICAL PROPERTIES

Material	Flexural Properties Strength ksi	Flexural Properties Strength GN/m²	Flexural Properties Modulus msi	Flexural Properties Modulus GN/m²	Shear Strength ksi	Shear Strength MN/m²	Instrumented Pendulum Impact Max. Load lbs	Instrumented Pendulum Impact Max. Load N	Instrumented Pendulum Impact Energy ft-lbs	Instrumented Pendulum Impact Energy joules
B/glass/polysulfone	195	1.33	18.5	127	9.2	63.5	244	1080	7.5	10.2
	188	1.30	18.5	127	10.0	69.0	244	1080	7.3	9.9
	174	1.20	18.7	129	9.5	66.5	230	1020	7.6	10.3
B/glass/epoxy	$>$ 271	$>$ 1.87	15.3	106	15.1	104	$>$ 487	$>$ 2160	10.1	13.7
	$>$ 278	$>$ 1.92	15.7	108	14.8	102	612	2710	8.8	10.9
	$>$ 284	$\geq$ 1.96	16.1	111	14.8	102	571	2540	8.6	10.7
T-300/glass/epoxy (UTRC)	253	1.74	18.8	130	9.8	67.5	$>$ 291	$>$ 1290	3.5	4.7
	266	1.83	19.0	131	9.9	68.2	357	1590	3.9	5.3
	250	1.72	18.4	127	9.8	67.5	342	1520	3.0	4.1
T-300/glass/epoxy (3M)					15.3	106				
					15.8	109				
					15.8	109				
AS/glass/epoxy					16.5	114				
					16.1	111				
					16.4	103				